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TITLE OF THE INVENTION

A CDMA RECEIVING DEVICE AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

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The present application is based on Japanese
priority application No. 2002-192090 filed on July 1,
2002 with the Japanese Patent Office, the entire
contents of that are hereby incorporated by
10 reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

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The present invention generally relates to
a CDMA receiving device and a CDMA receiving method,
and especially relates to the devices and the
methods in which CDMA received signals are equalized
or interference compensated.

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2. Description of the Related Art

As a next generation mobile communication
system for realizing wireless multimedia
communication, a digital cellular wireless
25 communication system employing DS-CDMA (Direct
Sequence Code Division Multiple Access) is now being
developed. In the CDMA communication system, a
plurality of channels or user transmitted
information are multiplexed using spreading codes
30 and transmitted through wireless communication path.

A mobile communication system is easily
affected by fading phenomenon resulted from random
changes in amplitude and phase having the maximum
35 frequency determined by the speed of a mobile
terminal and carrier frequency. Therefore, it is
much more difficult to stably receive signals in the

mobile communication system, compared with a fixed radio communication system.

Spread spectrum communications are
5 effective for alleviating degradation resulted from such frequency selective fading. In the spread spectrum communications, narrowband signals are spread to wideband prior to transmission, therefore even if there is an electric field strength loss at
10 a specific narrow frequency region, the transmitted information can be well recovered from other frequency regions. In other words, in the presence of narrowband interference, there is a significant advantage to employing spreading procedure. Since
15 the interference is introduced after the transmitted signal is spread, then, whereas the despreading operation at the receiver shrinks the desired signal back to its original bandwidth, at the same time it spreads the undesired signal interference in
20 bandwidth by the same amount, thus reducing its power spectral density.

And in the mobile communication system, a signal can be reflected by tall buildings or
25 mountains located far away to generate delayed waves, causing multipath fading.

In the direct sequence spreading system, the delayed waves become interference waves against
30 spreading codes, resulting in degradation in reception characteristics. One RAKE reception scheme of utilizing the delayed waves for improving the reception characteristics is proposed by Japanese Patent Laid-open 2001-40981, in which each
35 delayed wave propagated through each path is despread, and each delayed time is matched. And then each wave is weighted depending on its

reception level and added together. In order to solve the fading problem, two techniques, spectrum spreading and RAKE reception, are mainly employed.

5 As the mobile communication traffic increases, more transmission capacity is needed. And multilevel transmission is desired to be more developed. For example, 4PSK is employed at present, but in the future 16QAM and higher multilevel
10 modulation will be utilized. For higher multilevel modulations, the accuracy will be much more required in radio devices.

 On the other hand, in a conventional
15 multilevel modulation system such as CATV or fixed micro system, an equalizer is widely used. A typical equalizer is a transversal equalizer, in which tap coefficients for FIR filters are automatically calculated to adaptively equalize
20 delayed waves.

 This scheme has not yet been realized in mobile communication systems, but was proposed by Japanese Patent Laid-open 7-30519. For example, FIG.
25 1 shows a block diagram of a conventional CDMA receiving device. This assumes that only one radio wave from a terminal is received, for simplicity. An equalizer (EQL) 12 is placed between a receiving part (RX) 11 and a demodulator (13) having
30 despreading function at receiving side. This structure can eliminate distortion component of a transmission line. An equalizer 14 can be placed after the demodulator 13 as shown in FIG. 2.

35 FIG. 3 is a block diagram showing one example of a structure of the demodulator 13. The demodulator 13 comprises a timing adjusting part 15

and a despreading part 16.

FIG. 4 is a block diagram showing one example of a structure of the transversal equalizer.

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In the figure, the equalizer comprises cascaded unit time delay elements $20_1 \sim 20_8$ receiving input signals, multiplier $21_1 \sim 21_8$ for multiplying tap coefficients $C_{-4} \sim C_{+4}$ to input/output signals of the unit time delay elements, and an adder 22 for summing the multiplier outputs. The transversal equalizer can automatically calculate coefficients for FIR filters or IIR filters, and eliminate distortion and interference in transmission lines. FIG. 4 shows an example of 9 taps, but the tap length may be determined by system requirement.

In general, the tap coefficients $C_{-4} \sim C_{+4}$ are calculated by correlating amplitude information and error information of the signal while keeping their timings matched with each tap.

FIG. 5 shows an example of a tap coefficient calculating part of a transversal equalizer. In the figure, the tap coefficient calculating part comprises cascaded unit time delay elements $24_1 \sim 24_8$ receiving amplitude information, cascaded unit time delay elements $25_1 \sim 25_4$ receiving error information, and correlating elements $26_1 \sim 26_8$. The correlating elements perform correlating operation between amplitude information inputted/outputted from each unit time delay element $24_1 \sim 24_8$ and error information outputted from the unit time delay element 25_4 . Each of the equalizers 12 and 14 comprises the equalizing part shown in FIG. 4 and the tap

coefficient calculating part shown in FIG. 5.

In these figures, one-dimensional equalizer is shown for simplicity. Two-dimensional equalizer is generally used for 4PSK or higher multilevel communications, or I and Q channels of an orthogonal amplitude modulation system.

FIG. 6 shows the CDMA receiving device of FIG. 1 with controlling mechanism indicated. FIG. 7 shows the CDMA receiving device of FIG. 2 with controlling mechanism indicated. In FIGS. 6 and 7, two types of amplitude information feedbacks are shown, because there are plural ways of controlling.

As a first problem, in FIG. 6 for example, if the amplitude information is derived from the pre-stage, then the amplitude information is based on the spread signal and the error information is based on a despread signal. The equalizer 12 equalizes the spread signal. Accordingly, the equalized signal and the amplitude information, and the error information have different types or modes with respect to despreading, and therefore it is impossible to perform accurate correlating calculation in the coefficient calculating part shown in FIG. 5.

As a second problem, in FIG. 6, even when the amplitude information is derived from the output of the demodulator 13, a signal equalized by the equalizer 12 is a spread signal, and the amplitude information and error information are based on a despread signal. Accordingly, the equalized signal and the amplitude information, and the error information have different types or modes with respect to despreading, and therefore it is

impossible to perform accurate equalization on the input signal.

5 As a third problem, when a despread signal
outputted from a demodulator 13 is equalized by an
equalizer 14 as shown in FIG. 7, amplitude
information and error information are based on a
despread signal. A signal to be equalized by the
equalizer 14 is a spread signal. Accordingly, the
10 amplitude information and error information as
controlling signals for the equalizer 14 should be
based on a spread signal to perform accurate
equalization.

15 In the above explanation, an equalizer is
employed, but the present invention can be applied
to an interference compensation device such as an
interference canceller. One example of such
interference compensation device is shown in
20 "Experiments on Parallel-type Coherent Multi-Stage
Interference Canceller with Channel Estimation Using
Pilot and Decision-feedback Data Symbols in W-CDMA
Reverse Link", Technical Report of The Institute of
Electronics, Information and Communication Engineers,
25 RCS2000-130, p13-19. Another example is shown in
IEEE, Globecom' 93.11.29-12.2, p1677-1682, "Decision
Feedback Multistage Receivers for Asynchronous CDMA
Systems". In a case where an interference
30 compensation device such as a decision feedback
interference canceller is provided before or after
despreading, a controlling signal for controlling
the interference compensation device has the same
problem as in equalizers, and signal processing
controlled by a feedback signal also has the same
35 problem.

SUMMARY OF THE INVENTION

It is a general object of the present invention to provide a CDMA receiving device and method in which accurate equalization or interference compensation can be performed by adjusting controlling signals for controlling the equalization or interference compensation so that the controlling signals have the same types or modes.

Features and advantages of the present invention will be set forth in the description that follows, and in part will become apparent from the description and the accompanying drawings, or may be learned by practice of the invention according to the teachings provided in the description. Objects as well as other features and advantages of the present invention will be realized and attained by an apparatus and a method particularly pointed out in the specification in such full, clear, concise, and exact terms as to enable a person having ordinary skill in the art to practice the invention.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, the invention provides as follows.

The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; an equalizing unit for equalizing the received signal; a despreading unit for despreading the received signal; and a controlling signal adjusting unit for adjusting a despread signal obtained from the despreading unit and outputting the adjusted signal as a controlling signal for the equalizing unit.

The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; an interference
5 compensation unit for performing interference compensation on the received signal; a despreading unit for despreading the received signal; and a controlling signal adjusting unit for adjusting a despread signal obtained from the despreading unit
10 and outputting the adjusted signal as a controlling signal for the interference compensation unit.

The present invention provides a CDMA receiving device comprising: a receiving unit for
15 receiving a spread signal; a despreading unit for despreading the received signal; an equalizing unit for equalizing the despread signal; and a spreading unit for spreading amplitude information and error information outputted from the equalizing unit;
20 wherein the spread amplitude information and error information are used as controlling signals in the equalizing unit.

The present invention provides a CDMA
25 receiving device comprising: a receiving unit for receiving a spread signal; a despreading unit for despreading the received signal; an interference compensation unit for performing interference compensation on the despread signal; and a spreading
30 unit for spreading amplitude information and error information outputted from the interference compensation unit; wherein the spread amplitude information and error information are used as controlling signals in the interference compensation
35 unit.

The present invention provides a CDMA

receiving device comprising: a receiving unit for receiving a spread signal; an equalizing unit for equalizing the received signal; a despreading unit for despreading the equalized signal; and a
5 spreading unit for spreading amplitude information and error information outputted from the despreading unit; wherein the spread amplitude information and error information are used as controlling signals in the equalizing unit.

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The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; an interference compensation unit for performing interference
15 compensation on the received signal; a despreading unit for despreading the compensated signal; and a spreading unit for spreading amplitude information and error information outputted from the despreading unit; wherein the spread amplitude information and
20 error information are used as controlling signals in the interference compensation unit.

The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; an equalizing unit for equalizing the received signal; a despreading unit for despreading the equalized signal; and a
25 spreading unit for spreading error information outputted from the despreading unit; wherein the spread error information and amplitude information inputted to the equalizing unit are used as
30 controlling signals in the equalizing unit.

The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; an interference compensation unit for performing interference
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compensation on the received signal; a despreading unit for despreading the compensated signal; and a spreading unit for spreading error information outputted from the despreading unit; wherein the
5 spread error information and amplitude information inputted to the interference compensation unit are used as controlling signals in the interference compensation unit.

10 The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; a signal processing unit for performing signal processing on the received signal; a despreading unit for despreading the
15 received signal; and a controlling signal adjusting unit for adjusting a despread signal obtained from the despreading unit and outputting the adjusted signal as a controlling signal for the signal processing unit.

20 The present invention provides a CDMA receiving method comprising the steps of: receiving a spread signal; performing signal processing and despreading on the received signal; and adjusting a
25 despread signal obtained from the despreading step and outputting the adjusted signal as a controlling signal for the signal processing.

30 The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; a despreading unit for despreading the received signal; an equalizing unit for equalizing the despread signal; and a spreading unit for spreading amplitude information inputted to
35 the equalizing unit and error information outputted from the equalizing unit; wherein the spread amplitude information and error information are used

as controlling signals in the equalizing unit.

The present invention provides a CDMA receiving device comprising: a receiving unit for receiving a spread signal; a signal processing unit for performing signal processing on the received signal; a despreading unit for despreading the received signal; and a controlling signal adjusting unit for adjusting a signal fed back from the CDMA receiving device and outputting the adjusted signal as a controlling signal for the signal processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

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FIG.1 is a block diagram of a conventional CDMA receiving device;

FIG.2 is a block diagram of another conventional CDMA receiving device;

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FIG.3 is a block diagram of a demodulating part of a CDMA receiving device;

FIG.4 is a block diagram of an equalizing part of a transversal equalizer;

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FIG.5 is a block diagram of a tap coefficient calculating part of a transversal equalizer;

FIG.6 is a block diagram of a conventional CDMA receiving device similar to FIG. 1, illustrating controlling mechanism;

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FIG.7 is a block diagram of a conventional CDMA receiving device similar to FIG. 2, illustrating controlling mechanism;

FIG.8 is a block diagram illustrating a first principle of the present invention;

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FIG.9 is a block diagram illustrating a second principle of the present invention;

FIG.10 is a block diagram of a first

embodiment CDMA receiving device according to the first principle of the present invention;

FIG.11 is a block diagram of a second embodiment CDMA receiving device according to the first and second principles of the present invention;

FIG.12 is a block diagram of an equalizer according to the above embodiments of the present invention;

FIG.13 is a block diagram of a third embodiment CDMA receiving device performing RAKE receiving;

FIG.14 is a block diagram of a fourth embodiment CDMA receiving device performing RAKE receiving; and

FIG.15 is a block diagram of a fifth embodiment CDMA receiving device performing RAKE receiving;

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, embodiments of the present invention will be described with reference to the accompanying drawings.

First, the principle of the present invention is explained. In an equalizer according to the present invention, the type or mode of a signal to be equalized and the types or modes of controlling signals such as amplitude information, error information and tap coefficients for controlling equalization are matched with each other in order to provide desired equalization.

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FIG. 8 is a block diagram illustrating a first principle of the present invention. In this

block diagram, a decoder or demodulator 31 is provided after an equalizer 30. In this case, when obtaining amplitude information, error information and tap coefficients from the decoded type or
5 decoded mode, these parameters are supplied to a re-spreader 32, where these parameters are re-spread using spreading codes supplied from the demodulator 31 and then outputted to the equalizer 30. The re-spreading process should be performed in exactly
10 matched timing, and therefore the types or modes of the amplitude information, error information and tap coefficients can be matched with the type or mode of the inputted signal to the equalizer 30.

15 In all the embodiments explained in this Description, equalizers can be replaced with other signal processing devices such as an interference compensation device.

20 FIG. 9 is a block diagram illustrating a second principle of the present invention. In this block diagram, an equalizer 33 is provided after the decoder or demodulator 31. In this case, when obtaining amplitude information from the pre-
25 decoding type or pre-decoding mode, the amplitude information is supplied to a despreaders 34, where the amplitude information despread using spreading codes supplied from the demodulator 31 and outputted to the equalizer 33. The desreading process should
30 be performed in exactly matched timing, and therefore the type or mode of the amplitude information can be matched with the types or modes of error information and the inputted signal to the equalizer 33.

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FIG. 10 is a first embodiment block diagram of a CDMA receiving device in accordance

with the first principle of the present invention. In this figure, the same parts as those shown in FIG. 8 are assigned the same reference numerals. In FIG. 10, a DS-CDMA communication signal received at a receiver 29 is fed through an equalizer 30 to a decoder or demodulator 31, where the signal is timing-adjusted, despread and demodulated.

Amplitude information of the received signal is supplied to the equalizer 30. Error information of the demodulated signal (difference between the desired value and the actual demodulated signal value) is supplied to a re-spreader 32, where the error information is re-spread using spreading codes supplied from the demodulator 31 and then outputted to the equalizer 30. Based on the amplitude information and the error information having the same type or mode, the equalizer 30 calculates tap coefficients, equalizes the received signal using the calculated tap coefficients, and outputted the equalized signal to the demodulator 31.

If amplitude information obtained from the demodulated signal is utilized, the amplitude information after demodulation is supplied to a re-spreader 35 as indicated by a broken line, where the amplitude information is re-spread using the spreading codes supplied from the demodulator 31 and then outputted to the equalizer 30. Based on the amplitude information and the error information having the same type or mode supplied from the re-spreaders 35 and 32, the equalizer 30 calculates tap coefficients, equalizes the received signal using the calculated tap coefficients, and outputted the equalized signal to the demodulator 31.

FIG. 11 is a second embodiment block

diagram of a CDMA receiving device in accordance with the first and second principles of the present invention. In this figure, the same parts as those shown in FIGs. 9 and 10 are assigned the same reference numerals. In FIG. 11, a DS-CDMA communication signal received at a receiver 29 is fed to a decoder or demodulator 31, where the received signal is timing-adjusted, despread and demodulated. The demodulated signal is equalized by an equalizer 33 and outputted.

Amplitude information from the demodulator 31 is supplied to a re-spreader 36, where the amplitude information is re-spread using spreading codes supplied from the demodulator 31 and outputted to the equalizer 33. Error information outputted from the equalizer 33 is supplied to a re-spreader 38, where the error information is re-spread using the spreading codes supplied from the demodulator 31 and fed back to the equalizer 33. Based on these re-spread amplitude information and error information having the same type or mode, the equalizer 33 calculates tap coefficients, and equalizes the received signal using the calculated tap coefficients.

If amplitude information obtained from the output of the equalizer 33 is utilized, the amplitude information after equalization is supplied to a re-spreader 37 as indicated by a broken line, where the amplitude information is re-spread using the spreading codes supplied from the demodulator 31 and then fed back to the equalizer 33. Based on the amplitude information and the error information having the same type or mode supplied from the re-spreaders 37 and 38, the equalizer 33 calculates tap coefficients, equalizes the received signal using

the calculated tap coefficients, and outputted the equalized signal.

As explained above, if the error
5 information and amplitude information obtained from
the despread signal are used as they are for
calculating the tap coefficients, errors are
generated when shifting timing during the tap
coefficients calculation. In order to avoid this
10 problem, re-spreading of these parameters are
performed to avoid the influence of the despreading.
The tap coefficients calculated in this manner can
be utilized in pre-despreading type or mode. And if
thus obtained tap coefficients are utilized in an
15 equalizer in the post-despreading stage, the tap
coefficients are despread.

FIG. 12 is a block diagram of an equalizer
33 according to the above scheme of despreading the
20 tap coefficients. The equalizer 33 comprises an
equalizing part 33A shown in FIG. 12(A) and a tap
coefficient calculating part 33B shown in FIG. 12(B).
The equalizing part 33A has the same structure as
the equalizing part shown in FIG. 4, and therefore
25 its explanation is omitted. The tap coefficient
calculation part 33B has the same structure as the
tap coefficient calculation part shown in FIG. 5,
and therefore its explanation is omitted.

30 In FIG. 12(A), spreading codes supplied
from the demodulator 31 are sequentially delayed by
cascaded unit time delay elements $41_1 \sim 41_n$. Each
of inputted and outputted signals of the unit time
delay elements are supplied to each of multiplier
35 $42_1 \sim 42_n$, respectively. Each of tap coefficients
outputted from the coefficient calculation part 40
are supplied to each of the multiplier $42_1 \sim 42_n$,

respectively, and are despread using each of the spreading codes respectively to obtain the despread tap coefficients $C_{-4} \sim C_{+4}$, which are supplied to each of the multipliers $21_1 \sim 21_9$.

5

In the example shown in FIG. 12, the despread process is performed on the tap coefficients to be operated later on the input signal. However, after the tap coefficients are operated on the input signal, the despread process can be performed to obtain a similar result. That is, the order of these two operations can be changed.

15 In the above examples, only one radio wave from a transmitter is explained for simplicity. However, in the actual mobile communication system, it is more general that a signal can travel from a transmitter to a receiver over multiple reflective paths; this phenomenon is referred to as multipath propagation. The effect can cause fluctuations in the received signal's amplitude, phase and angle of arrival, that is multipath fading. And most receivers have a plurality of antennas. In this condition, a plurality of demodulators can be provided to demodulate each of the plurality of propagated radio waves and mix the demodulated signals, that is RAKE receiving.

30 FIG. 13 is a third embodiment block diagram of a CDMA receiving device performing RAKE receiving. In this figure, a plurality of propagated radio waves acquired by antennas $50_a \sim 50_c$ are received by receiving parts $51_a \sim 51_c$, respectively. The DS-CDMA signals received at the receiving parts $51_a \sim 51_c$ are supplied through equalizers $52_a \sim 52_c$ to demodulators $53_a \sim 53_c$, where

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the signals are timing-adjusted, despread and demodulated, and delayed by desired time respectively.

5 Amplitude information of each of the received signals is supplied to one of the equalizer 52_a ~ 52_c, respectively. Error information of each of the demodulated signals (difference between the
10 value) is supplied to one of re-spreaders 54_a ~ 54_c, where the error information is respread using spreading codes supplied from the demodulators 53_a ~ 53_c.

15 Based on the respective amplitude information and the error information having the same type or mode, each of the equalizers 52_a ~ 52_c calculates tap coefficients, and equalizes the
20 received signal using the calculated tap coefficients, and outputted the equalized signal to each of the demodulators 53_a ~ 53_c, respectively. Demodulated signals outputted by each of demodulators 53_a ~ 53_c, with given an adequate delay
25 respectively, are mixed at summing parts 55 and 56, and then the mixed signal are outputted.

FIG. 14 is a fourth embodiment block diagram of a CDMA receiving device performing RAKE receiving. In this figure, the same parts as those
30 shown in FIG. 13 are assigned the same reference numerals. In FIG. 14, a plurality of propagated radio waves acquired by antennas 50_a - 50_c are received by receiving parts 51_a - 51_c, respectively. Two radio waves (paths) having different time delays
35 are acquired by the antenna 50_a.

The DS-CDMA signals received at the

receiving parts 51_a ~ 51_c are supplied through
equalizers 52_a ~ 52_c to demodulators 53_{a1}, 53_{a2}, 53_b,
53_c. The two different path signals equalized by
the equalizers 52_a are separately supplied to the
5 demodulators 53_{a1} and 53_{a2}. Each of the demodulators
53_{a1} and 53_{a2} adjusts the timing of each of the
equalized signals, despreads and demodulates the
timing-adjusted signal to output them with adequate
delays respectively.

10
Amplitude information of each of the
received signals is supplied to each of the
equalizers 52_a ~ 52_c. Error information obtained
from the demodulators 53_{a1} and 53_{a2} are mixed at a
15 mixer 57. The mixing way at the mixer 57 is simple
addition or selection of an errorless signal, and so
on. The mixed error information is supplied to the
re-spreader 54_a. Error information obtained from
the demodulators 53_b and 53_c are supplied to the re-
20 demodulators 54_b and 54_c. The re-spreaders 54_a -
54_c utilize spreading codes supplied from the
demodulators 53_{a1}, 53_b, 53_c, to re-spread each of the
error information respectively, and supplied each of
the re-spread error information to each of the
25 equalizers 52_a ~ 52_c. Based on the amplitude
information and error information having the same
type or mode, each of the equalizers 52_a ~ 52_c
calculates tap coefficients, equalizes the received
signal using the calculated coefficients, and
30 supplied the equalized signal to each of the
demodulators 53_{a1}, 53_{a2}, 53_b, 53_c.

The demodulated signals outputted from the
demodulators 53_{a1}, 53_{a2}, with given adequate delays,
35 are added together at an adder 58, and supplied to
an adder 55. The demodulated signals outputted from
the demodulator 53_b and 53_c are given adequate

delays respectively and added together at an adder 56, and supplied to the adder 55, where they are added to the demodulated and added signal from the adder 58 and outputted. In this embodiment, the
5 distortions simultaneously affected to the two paths can be equalized.

FIG. 15 is a fifth embodiment block diagram of a CDMA receiving device performing RAKE
10 receiving. In this figure, the same parts as those shown in FIG. 14 are assigned the same reference numerals. In FIG. 15, a plurality of propagated radio waves acquired by antennas 50_a ~ 50_c are received by receiving parts 51_a ~ 51_c, respectively.
15 Two radio waves (paths) having different time delays are acquired by the antenna 50_a.

Two path received signals of the DS-CDMA signals received at the receiving parts 51_a are
20 supplied through equalizers 52_{a1}, 52_{a2} to demodulators 53_{a1}, 53_{a2}. The signals of the DS-CDMA received at the receiving parts 52_b, 52_c are supplied through equalizers 52_b, 52_c to demodulators 53_b, 53_c. Each of the demodulators 53_{a1}, 53_{a2}, 53_b, 53_c adjusts
25 the timings of the received signals, despreads them to demodulate, and further gives an adequate delay time to each of the demodulated signals respectively and output.

30 Amplitude information of each of the received signals is supplied to each of the equalizers 52_a ~ 52_c. Error information of each of the demodulated signals from the demodulators 53_{a1}, 53_{a2} is supplied to re-spreaders 54_{a1}, 54_{a2},
35 respectively. Error information of the demodulated signals from the demodulators 53_b, 53_c is supplied to re-spreaders 54_b, 54_c. Each of the re-spreaders

54_{a1}, 54_{a2}, 54_b, 54_c re-spreads each of the error information respectively, using spreading codes supplied from the demodulators 53_{a1}, 53_{a2}, 53_b, 53_c, and supplied each of the re-spread error information to each of the equalizers 52_{a1}, 52_{a2}, 52_b, 52_c, respectively.

Based on the amplitude information and error information having the same type or mode, each of the equalizers 52_{a1}, 52_{a2}, 52_b, 52_c calculates tap coefficients, equalizes the received signal using the calculated tap coefficients, and supplies each of the equalized signals to each of the demodulators 53_{a1}, 53_{a2}, 53_b, 53_c, respectively.

The demodulated signals outputted from the demodulators 53_{a1}, 53_{a2}, with given adequate delays, are added together at an adder 58, and supplied to an adder 55. The demodulated signals outputted from the demodulator 53_b and 53_c are given adequate delays respectively and added together at an adder 56, and supplied to the adder 55, where they are added to the demodulated and added signal from the adder 58 and outputted. In this embodiment, the equalization process is performed for each antenna and for each path, and therefore distortions simultaneously affected to the two paths can be equalized, and distortions affected on propagation paths also can be equalized.

In the embodiments shown in FIGs. 13, 14 and 15, the demodulation process is performed after the equalization. However, the equalization process can be performed after the demodulation as shown in FIG. 11, and the present invention is not limited to the above embodiments.

In the above embodiments, the explanations are given with respect to the equalization process, but the present invention can also be applied to interference compensation to solve the problem of condition or stage of controlling signals in a similar manner.

The above explained re-spreaders 32, 35 ~ 38 are included in a controlling signal adjusting unit and a spreading unit described in claims. "Signal processing" referred to in this Description and Claims includes any signal processing that is controlled by a controlling signal fed back from its own output terminal, such as equalization process and interference compensation process.

According to the embodiments of the present invention, controlling signals for equalization such as amplitude information and error information are adjusted to adequate type or mode to perform the precise equalization.

According to the embodiments of the present invention, controlling signals for interference compensation such as amplitude information and error information are adjusted to adequate dimension or mode to perform the precise interference compensation.

According to the embodiments of the present invention, controlling signals for signal processing such as amplitude information and error information are adjusted to adequate dimension or mode to perform the precise signal processing.

Further, the present invention is not limited to these embodiments, but various variations

and modifications may be made without departing from the scope of the present invention.